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Streamflow Information for the Next Century

A Plan for the National Streamflow Information Program of the U.S. Geological Survey

A Proposed Plan

- To increase the level of streamflow information for National needs;
- To improve the way streamgaging stations are funded and located;
- Of new ways to collect, store, and distribute streamflow information.

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Open-File Report 99–456

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Streamflow Information for the Next Century—A Plan for the National Streamflow Information Program of the U.S. Geological Survey

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- **To increase the level of streamflow information for National needs;**
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U.S. DEPARTMENT OF THE INTERIOR
Bruce Babbitt, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

Copies of this report available upon request from:

U.S. Geological Survey
Information Services
Box 25286
Federal Center
Denver CO 80225

For additional information about this report contact:

Chief, Office of Surface Water
U.S. Geological Survey
12201 Sunrise Valley Drive
Mail Stop 415
Reston VA 20192

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INTRODUCTION

Since 1889, the U.S. Geological Survey (USGS) has operated a multipurpose streamgaging network supported primarily by other Federal, State, and local agencies. Streamgaging stations are the monitoring tools used to track the flux of water and associated components in streams and rivers across the Nation. Streamflow data from them are used for planning and decisions related to agriculture, industry, urban water supplies, navigation, riverine and riparian habitat, and flood hazard identification. The principles that have guided this national network are:

- Many partners contribute funding for the operation of gaging stations to collaboratively achieve Federal mission goals and the individual goals of the funding agencies.
- All data are freely available to all partners and the public.
- USGS operates the network on behalf of all partners to achieve economy and standardization of availability and quality of data.

These goals remain appropriate and applicable today. However, the multipurpose streamgaging network needs increased resources and reorientation because of deficiencies in the present network to meet Federal goals, changing instrumentation and communication technology, and new opportunities to integrate our streamflow data with information from other Federal agencies.

> ***"Streamflow data collected by the USGS for over 100 years and the modern water science and technology carried out by the WRD form the cornerstone for national, regional, and local efforts to cope with hydrologic hazards by providing continued, up-to-date information about water conditions and understanding of hydrologic phenomena." (From Preface, Hydrologic Hazards Science at the U.S. Geological Survey, National Research Council, 1999, p. viii).***

In response to a recent Congressional request, the USGS completed an evaluation of the ability of the streamgaging network to meet Federal needs for streamflow information (U.S. Geological Survey, 1998). The report found that the degree of attainment of the Federal needs rose steadily through the 1960s and 1970s and then leveled off or declined. Some goals are now less well supported than in the 1950s and 1960s. During the 1990s, the number of stations significantly decreased. Funding from the USGS has become a smaller and smaller component of the collaborative network; the shrinking proportion of USGS funding for the network continues to reduce the ability of the network to meet Federal interests (fig. 1).

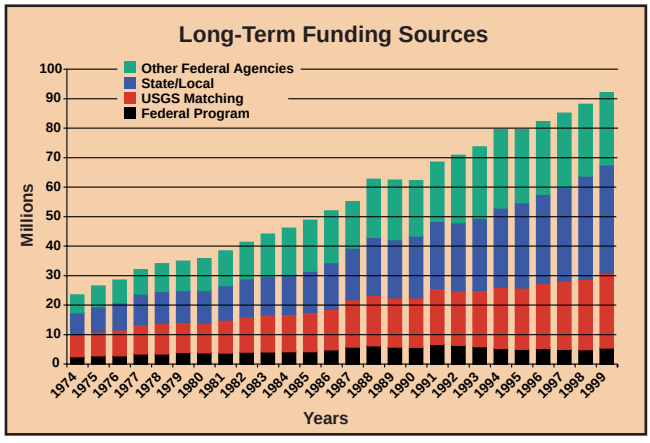

Figure 1. *Funding sources for USGS streamgaging stations for fiscal years 1974-99.*

The number of gaging stations has declined for a decade, more and more costs are borne by non-Federal partners, and the loss of stations with long-term records is accelerating.

The present approach to providing streamflow information is rapidly becoming inadequate and unstable. The reasons relate to two fundamental changes that affect the network. The first change is that USGS funds have become a smaller share of the total network funding, dropping from 43 to 33 percent, respectively, between fiscal years 1974 and 1999. This has caused the network to be more vulnerable as funding partners consider their own specific needs. In some cases, they have decided to do without the information or undertake alternative approaches that provide more limited information. For example, they may decide to measure flows for only part of the year, or focus on low flows or high flows, or only provide stage data and not discharge. Costs can be lowered when they choose to not provide a capability for public data access, or to limit access to either real-time or historical data. Costs can also be reduced by not including quality assurance or by making fewer visits to inspect instruments and make discharge measurements. These kinds of cost-cutting measures may be rational for the current needs of a partner agency. However, from a national interest perspective they are sub-optimal, because what is lost is a public good that has wide applicability for many uses. The loss of 22 percent of the streamgaging stations that record flow on small, free-flowing rivers since 1971 is one example of the impact of the funding changes. This loss of streamflow information is compounded because often the discontinued streamgaging stations have long historical records, which are essential for effective assessment and planning of water-resources programs by Federal, State, and local governments (fig. 2).

The second change is that the network now has a broader set of uses, but specific partners willing to support these new uses have not emerged. Some of the new uses arise from changes in society's interests. These include the need for flow data to support: water-quality management, aquatic-habitat improvements, enhanced operations at dams, water-based recreation, and a public and scientific interest in long-term environmental change. Beneficiaries for these uses are often diffuse, and thus the services are under- provided because no one is prepared to step forward to pay for them. This is what economists call the "free rider problem," a well-known issue in terms of provision of government services.

New uses also arise from advances in technology. In particular, satellite telemetry in conjunction with the use of the World Wide Web (WWW) has greatly enhanced the value of the data and also the demand and expectations about its availability and reliability. The Internet can now be used to provide current data on floods and recreational flow conditions. However, these technologies have significant infrastructure costs and demand a level of reliability of service that was never before required of the USGS. To make the present partners bear these costs alone, given that the benefits of the technologies are widespread, is unfair and unrealistic.

In addition to funding and infrastructure issues, other components of the network require reassessment. These include documenting floods and droughts,

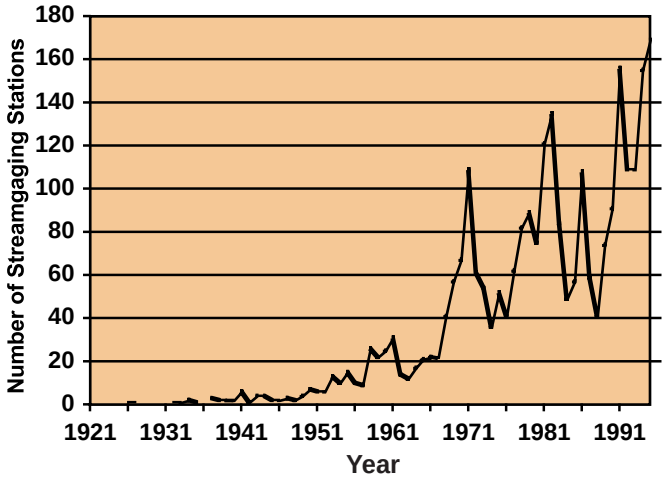

Figure 2. *Annual loss of streamgaging stations with more than 30 years of record.*

assessing streamflow trends, and developing systems for improving the monitoring and dissemination of streamflow data and related information. Current opportunities to document the characteristics and distributions of floods and droughts are limited to those events when supplemental funds are appropriated after a Presidential Declaration of a Disaster. USGS should have base funds for post-event data collection to provide valuable information for characterizing the events and to help mitigate the effects of future events. Likewise, there is a need for ongoing assessments of streamflow data at the national and regional level so that water-resource managers, planners, engineers, forecasters, and emergency management officials have the most current statistical information on floods and droughts. The expanding demand for real-time streamflow data and timely assessments of streamflow characteristics and trends requires that new capabilities be developed both for monitoring of conditions at field sites and for disseminating reliable and accurate data and results of assessments to many thousands of users nationwide. The approaches described in this report attempt to respond to the changing circumstances of the streamgaging infrastructure in a way that serves both the specific needs of partners and the broader national interest for streamflow information.

A PROPOSED NATIONAL STREAMFLOW INFORMATION PROGRAM

A USGS Committee reexamined its streamgaging program, evaluating not only the streamgaging stations but the full suite of products derived from the network. The Committee recommended initiating the **National Streamflow Information Program (NSIP)**. The NSIP will produce information for multiple uses, be shared freely, made readily accessible for current use, archived for future use, be quality assured, and be viewed as neutral, objective, and of high quality by all parties. NSIP will consist of the following components:

1. A nationwide system of Federal-interest streamgaging stations for measuring streamflow and related environmental variables (precipitation, temperature) reliably and continuously in time;
2. A program for intensive data collection in response to major floods and droughts;
3. A program for periodic assessments and interpretation of streamflow data to better define its statistical characteristics and trends;
4. A system for real-time streamflow information delivery to customers that includes data processing, quality assurance, archival, and access;
5. A program of techniques development and research.

Many of the features of NSIP are consistent with recent recommendations of the National Research Council (1992, 1999). Providing timely, reliable information that can be used for many decisions by many parties is the goal of NSIP. The purpose of this report is to define NSIP and give the motivation of its conceptual design and seek input from the many funding partners and users of streamflow information. This process will lead to detailed funding and implementation plans for the NSIP.

Federal-Interest Streamflow Network

Federal streamflow information needs are those that should be met by the USGS streamgaging network even in the absence of support from funding partners. These include:

Compacts and Decrees for Interstate and International Transfers (350 locations). Interstate compacts, court decrees, and international treaties mandate streamgaging by the USGS at State-line-crossings and other points of flow adjudication.

Federal streamflow information needs are those that should be met by the USGS streamgaging network even in the absence of support from funding partners.

National Weather Service (NWS) Flood Forecasts (2,950 locations served).
Real-time discharge and stage data are required in support of NWS river forecasts and flood warnings at service locations across the country.

Water Budgets (329 accounting units monitored).
Tracking and quantifying the volumes and flow rates of water from upland watersheds to major rivers as it moves through the drainage systems of the Nation to assist in national water assessments, planning studies, and policy decisions.

Regionalization and Long-term Trends (800 stations).
Regionalization is the process of using a representative flow record as a surrogate for other locations where streamgaging stations do not exist. It is the backbone of USGS methods for estimating streamflow characteristics at ungaged locations. To reduce errors in existing regional relations, and to estimate changes in flow characteristics that result from environmental changes, at least one streamgaging station is required for every unique ecoregion and water-budget accounting-unit combination in the Nation.

Water Quality (850 stations)
The water-quality goal has been modified slightly from the Report to Congress to include two components. The first component is a minimal Federal network of streamgaging stations that are needed to support three national water-quality networks operated by the USGS. These networks are the National Stream Quality Accounting Network (NASQAN), a set of 40 stations that cover the Nation's largest rivers; the National Water Quality Assessment (NAWQA) low-intensity network, a set of 62 stations that cover intermediate-sized rivers; and Benchmark, a set of 48 small pristine watersheds. The second component includes locations where streamflow information is needed for planning and implementing restoration efforts to improve water quality in those watersheds that are known to have degraded water quality. It is anticipated this list will change over time as new information is obtained, but that there will be a continual need for streamflow information in support of water-quality improvement activities in about 700 watersheds nationwide.

The list of Federal needs presented here and in table 1 represents our view of the most important needs from a Federal perspective. Review and comment on this definition of core needs will be sought from many stakeholders and from the National Research Council. Reactions to this definition of core needs must be made with the recognition that it represents a "floor" and not a "ceiling" for the needs that should be addressed by a Federal streamgaging network.

Table 1. *Base Federal-interest streamgaging goals, with levels of attainment in 1996 and number of additional streamgaging stations required to meet goals*

Base Federal Interest	Number of sites or reaches to be served	Level of attainment of goal in 1996, in percent	Number of additional streamgaging stations needed to meet goal
Compacts and Decrees	350	56	150
NWS Flood-Forecast Sites	2950	73	800
Water Budgets	350	77	100
Long-term Changes	800	76	200
Water Quality	700	88	100
TOTAL			1,350

To meet the streamgaging needs defined by the list of Federal interests we propose to:

- Evaluate the current USGS streamgaging network for meeting defined Federal needs; identify locations that require additional streamgaging stations.
- Evaluate streamgaging stations operated by Federal partners and cooperators that are properly located to fill one or more Federal needs; evaluate what modifications in equipment or operation are needed to meet Federal streamgaging station goals; provide support for necessary upgrades.
- Consider reactivated or new stations to fulfill the remainder of the Federal needs.

Other Federal Streamflow Interests

It must be emphasized that the Federal interests discussed above are a base level and do not represent the full range of Federal streamflow information needs. Other important Federal interests are:

- Information for sites needing flood forecasts that are not presently served by NWS.
- Federal Emergency Management Agency (FEMA) requirements for flood-insurance-rate maps.
- Streamflow information to support effective stewardship of Federal lands.
- Widespread monitoring in support of water-quality standards, waste-water discharge allocations, restoration efforts, and recovery plans for threatened or endangered aquatic species.
- Data for national water-use assessments.
- Data to support operation and management of major Federal reservoirs.
- Real-time monitoring of flow in Wild and Scenic Rivers.

New Funding Mechanism

The report of the Review of the Federal-State Cooperative Water Program (in press) recommended that the USGS:

> ***"Establish an adequate and permanent streamflow monitoring network in the National interest. Funding for long-term data collection should be stressed as a national priority. The Task Force supports the concept that the federal government should provide 100% funding for a national stream-gaging network, and that the funding for this network should not come at the expense of the Cooperative Water Program."***

Emery Cleaves, the Maryland State Geologist, speaking for the Association of American State Geologists, offered this statement in an article in Geotimes on stream gaging:

> ***"The federal government should fund the entire cost of a base-line, national network of stream gages that measures the 'pulse' of the nation's surface-water resources."***

Uncertainties in funding from year to year have led to a fragmented network of streamgaging stations that come and go, and thus have shorter periods of record on which to make estimates of future flow conditions or monitor streamflow trends. Sometimes the search for funding partners is unsuccessful, and critical national interests go unmet, as was the case along the Liking River, Kentucky:

> ***On 1 March 1997, northern Kentucky was drenched with up to 25 centimeters of rain. The Licking River, which meanders through the town of Falmouth, rose a meter in only 3 hours and kept on rising. By evening, Falmouth's emergency siren was wailing and police were shouting evacuation orders through bullhorns. Most of the 2400 residents managed to flee, but the water came so fast, even shoving houses off their foundations, that some had to be rescued from rooftops. Four people in mobile homes drowned. The river had crested 4 meters higher and 6 hours earlier than the National Weather Service (NWS) had predicted. NWS officials admitted that they had underestimated the danger, but added that their forecasts had been severely hampered by the loss of a crucial gaging station 32 kilometers upriver, which was cut in a budget crisis in 1994. "It was like a flash***

Streamgaging stations that satisfy the defined Federal interests should be funded entirely by Federal appropriation.

Flooding in Grand Forks, North Dakota, during the 1997 flood.

flood," says Mark Callahan of the NWS's Louisville office. "Without that gage, we were blind." (Science, Aug. 23, 1999)

One of the weaknesses of the current network is the funding mechanism. Funding partners are required to pay an amount that represents the total cost of the network divided by the number of gages. This amount encompasses a share of the fixed costs that are associated with the very existence of the network and the marginal cost of operating a streamgaging station in the network. Fixed costs include the data-management and dissemination system, technology development and testing, quality assurance, and network management. Current (1999) estimates are that about 40 percent of the average cost of operating a station are fixed costs or about $37 million per year for the current network. Under NSIP the fixed costs of the network would be covered through federal appropriations. The marginal costs of operating a streamgaging station include personnel costs associated with inspecting the station, making discharge measurements, and computing and publishing the data; the amortized cost of the instruments and communication equipment; the cost of periodic maintenance and repairs; and the travel expenses for the site visits.

Under the NSIP concept, the total cost of those streamgaging stations needed to meet the base Federal needs would be covered by Federal appropriations. For totally new stations, these would include a first-year installation cost of $20,000 to $50,000 per station. The cost would be lower for reactivating former USGS stations or for upgrading stations operated by others. However, there are significant additional costs that may be required for many existing stations to meet the requirements of a base Federal network station. The marginal costs of station operations, to be funded by the Federal appropriations for the base Federal network, are expected to average about $6,000 per year.

Other streamgaging stations in NSIP would still require funding from partners. The Federal-State Cooperative Water Program would continue to be a major mechanism for funding those stations that meet identified Federal needs but are not a part of the base Federal network. The annual marginal costs of operation would be shared by the USGS and its partners with no more than 50 percent of the marginal costs paid from USGS appropriations. Streamgaging stations needed to meet the needs of other Federal agencies would have their marginal costs fully funded by the requesting agency. The USGS however, would continue to work collectively with many agencies to build coalitions of funding partners to share the costs of stations that serve many needs. At such time as the NSIP plans may become accepted and implementation begins, detailed cost estimation and transition planning will be done. The proposed shift in the funding paradigm is a significant one, and reactions of funding partners will need to be considered carefully. Over time, the proposed funding mechanism would lead to more stability, not only in the base Federal part of the network but also in the cooperatively funded part as well.

The fixed costs of the USGS stream gaging program should be funded by Federal appropriation.

The marginal costs for non-Federal base need streamgaging stations would be funded by partners.

A New Mode of Operation

Presently, about two-thirds of USGS-operated streamgaging stations have real-time telemetry capability. Under NSIP, where telemetry is appropriate and possible, USGS gaging stations should be equipped to enable real-time data. Where appropriate, water-quality data, such as temperature and specific conductance would be collected at streamgaging stations on a continuous basis. Other water-quality measures would be collected as funding opportunities and needs arise. A full-service Federal-interest streamflow and water-quality station could eventually include continuous information on stage and discharge, and a suite of water-quality parameters, such as temperature, specific conductance (a measure of salinity), pH, dissolved oxygen, suspended sediment, bacteria, metals, and organic constituents. A nationwide network of streamgaging stations that collects important selected water-quality data would provide a valuable source of information for monitoring habitat, tracking sources of contamination, computing loads of contaminants during floods, viewing water-quality-conditions at a regional scale, and planning the restoration of degraded streams, rivers, and lakes.

Protecting Stations from Floods

Many streamgaging stations are at risk during times of flood. The location and physical condition of these stations cause them to be damaged or inundated during major floods. Thus, important information may not available to forecasters and emergency managers when it is needed most. Under NSIP, critical USGS streamgaging stations would be hardened to withstand flows up to the 200-year flood level. All critical stations would have a stream-to-WWW data-delivery reliability of 99 percent. A program of streamgaging-station hardening will significantly decrease the need for the USGS to seek supplemental appropriations for station repairs when catastrophic floods occur.

Intensive Data-Collection during Floods and Droughts

Floods and droughts are extreme events of the hydrologic surface-water flow system. As such, they define the points of concern of natural and constructed surface-water systems, such as water supply, channel capacity, water quality, and habitat. The summer drought in the eastern United States in 1999 highlighted how vulnerable the Nation is to water shortages.

The NSIP approach to data collection for floods and droughts will be to supplement data from streamgaging stations with systematic field surveys. Every flood and drought is unique, but a standardized approach to field work and data collection will ensure that the important aspects of each event are documented. Data collected during these events will include information about precipitation duration/frequency, river stage and discharge, and opportunistic sampling of water-quality variables to include suspended sediment, nutrients, specific conductance, alkalinity, bacteria, pesticides, and hydrocarbons. Changes in geomorphology of river channels, such as river-bank erosion location and processes, and sedimentation volumes and distribution would be documented for high- as well as low-flow conditions.

Critical USGS gaging stations would be hardened to withstand flows up to the 200-year flood.

Important information from floods and droughts will be documented.

Flooded USGS streamgaging station on the Falling River near Juliette, Georgia.

For example, figure 3 shows the changing concentrations of herbicides in runoff from the Flint River at Newton, Georgia, from Tropical Storm Alberto in July 1994. These data show that highest concentrations occurred 4 to 6 days prior to the peak discharge on this river. Such data are valuable to track loads of contaminants, the timing of their transport, and to monitor the impact on downstream ecosystems. Such data should be available for many gaging stations across the country for many purposes, including knowing when toxic plumes have passed water-supply intakes and when to reopen water recreational sites.

Drought conditions

Flood conditions

Streamflow information would be interpreted on national and regional scales.

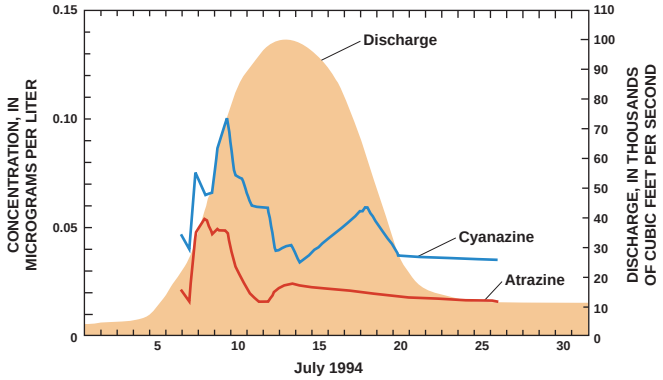

Figure 3. *Flux of herbicides in runoff from the Flint River, Georgia from Tropical Storm Alberto, July 1994.*

National Streamflow Assessments

The value of streamflow data from individual streamgaging stations is multiplied when the records are subjected to systematic analysis and interpretation. Streamflow records from any gaged site contain information not only on the actual history of streamflow during the period of record, but also on the statistical properties (means, flood recurrence intervals, low-flow characteristics, and so forth) of the streamflow process. The similarity of hydrologic response across basins allows information from gaged basins to be used in estimation of the streamflow characteristics of ungaged basins by means of regionalization (Wahl and others, 1995). Because the number of small, ungaged stream basins will always far exceed the number of gaged basins, regionalization is a crucial component of the overall USGS program of streamflow information processing. Current (1999) methods of regionalization typically estimate streamflow characteristics for ungaged basins with a standard error in the range of 40 to 70 percent.

The institution of a program of data interpretation would reveal regional and national patterns of streamflow characteristics and their temporal trends. Human modifications to runoff characteristics that are likely to be reflected in streamflow data include reservoir construction, dam removal, changing land use, ground-water pumpage, water consumption, channel alterations, and interbasin transfers. For example, in southeastern Wisconsin, long-term flow data from the Sugar River gaging station near Brodhead, show that annual flood peaks have decreased by 30 percent, and annual 7-day low flows increased by 25 percent, likely in response to improved agricultural land practices (fig. 4)

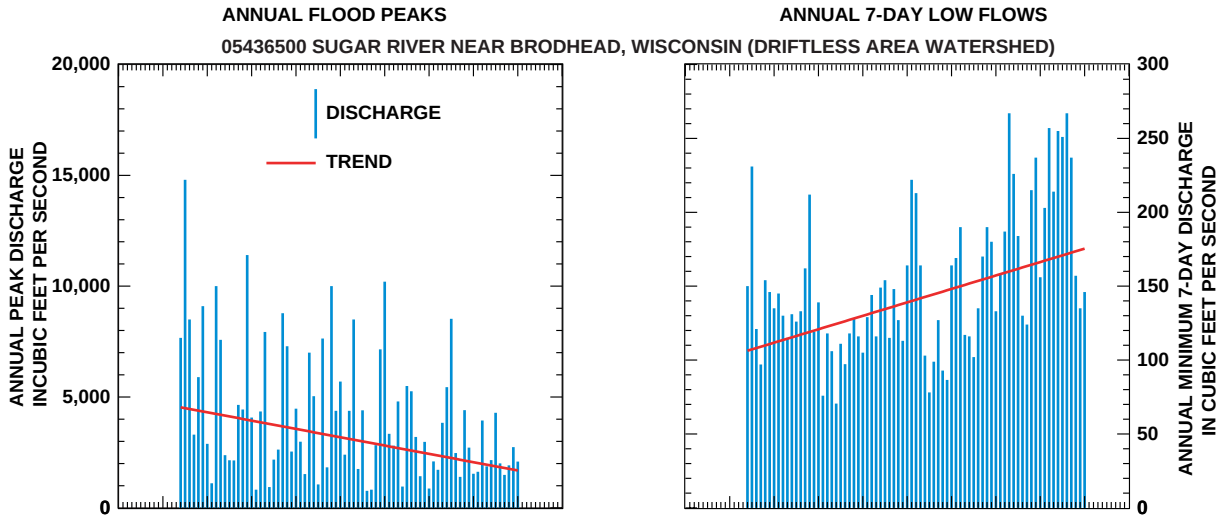

Figure 4. *Long-term changes in streamflow of the Sugar River in Wisconsin (from Gebert and Krug, 1996)*

The program will address such questions as "Has flooding increased in the Nation in recent years? What are the impacts of El Nino Southern Oscillation (ENSO) on the national water supply? Can we see the effects of greenhouse warming in the national streamflow record?" The value of information from long-term streamgaging stations for these types of analyses are demonstrated in figure 5. An estimate of the 100-year flood for the Chehalis River in Washington was determined in 1976 using over 40 years of streamflow record. This estimate of about 55,000 cubic feet per second was used for a FEMA Flood Insurance Study. In 1996, the 100-year flood for the Chehalis River was again estimated but with an additional 20 years of streamflow record to use in the calculation. The 1996 estimate of the 100-year flood was about 72,000 cubic feet per second, an increase of 31 percent over the 1976 estimate.

Enhanced Streamflow Information Delivery and Products

The USGS customer base has expanded rapidly as a result of WWW dissemination of near real-time streamflow information. The introduction of an efficient information delivery mechanism has significantly grown and diversified the market for USGS streamflow products. Further development of the WWW user interface(s) to near real-time and historical streamflow data would improve service to current customers and increase the customer base. WWW access to other information products (for example, streamflow characteristics) could be expected to have a similar effect. Accordingly, NSIP will provide convenient, reliable access to all of its information products through the WWW.

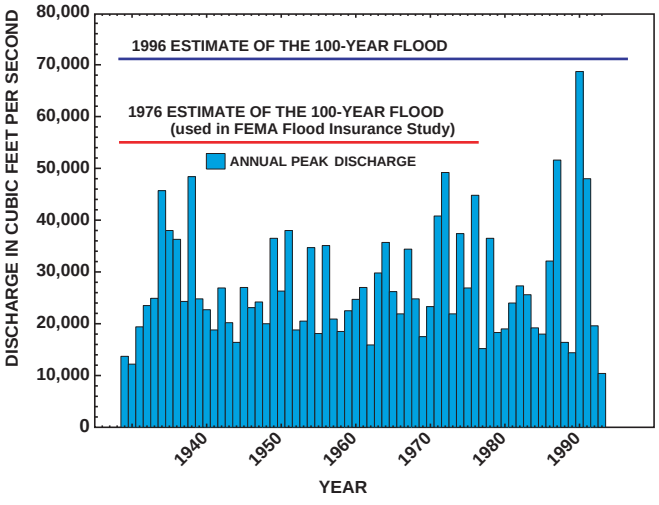

Figure 5. *Variation in estimates of the 100-year flood for two different time periods for the Chehalis River near Grand Mound, Washington.*

"In my work, whether as a real estate broker in the Berkshire Hills of western Massachusetts, as a Conservation Commissioner for my town of Stockbridge, or as a local watershed project coordinator for the Housatonic Valley Association, USGS map products and on-line web sites provide exceptional value for my tax dollar because they empower all of us to do far better work than we could do on our own. That's what I have always thought government was supposed to do, and you-all have hit the mark dead center." (Shepley W. Evans, Stockbridge, Massachusetts)

The current convention of providing routine access only to daily streamflow values does not meet the needs of many customers. Data at finer time scales are critical to water-quality analyses, habitat studies, and planning for flood control and water regulation. The existing focus on daily streamflow values is an artifact of the era when paper reports were the primary means of data dissemination. Under NSIP, all available stage and streamflow data will typically be disseminated at the time resolution of actual measurement (usually 15, 30, or 60 minutes) and as user-requested time averages (daily, monthly, and annual) through an interface that unifies historical and real-time data bases.

The USGS will develop partnerships for information delivery with other agencies. For example, NWS streamflow forecasts and USGS streamflow measurements are similar types of time-series data. Where USGS gage sites and NWS forecast service locations coincide, the USGS will provide unified graphical presentations of NWS forecasts in the context of USGS measurements and streamflow characteristics.

Recently, the USGS began serving maps with national coverage of flow conditions at real-time streamgaging stations (figure 6). The map depicts color-coded USGS gaging stations whose color represents discharge as a percentile, which is computed from the period of record for the current day of the year. Only stations having at least 30 years of record

NSIP will provide convenient and reliable access to all of its information products through the World Wide Web.

are used. This provides a real-time, small-scale view of the Nation's surface-water circulatory system. Figure 6 shows such a display that reflects the height of the drought in the Northeast in the summer 1999.

> ***"Streamflow gaging stations are diminishing in number at a time when most other sources of other types of hydrologic data are increasing. With the ever-present importance of the calibration and verification of hydrologic models, and the increasing availability of rainfall estimates from the NEXRAD system, the decline in stream flow gaging stations is alarming… At present, the USGS funding of the Cooperative Program is over-matched. That is, there are more state, local, and tribal dollars than federal dollars spent on stream gaging. This lack of balance may result in a further significant reduction in the number of stream gaging stations if state, local, or tribal entities reduce their budgets for stream gaging. The decline in the number of stream flow gaging stations must be halted." (American Society of Civil Engineers Task Committee on GIS Modules and Distributed Models of the Watershed Report, 1999, p. 63-64).***

The USGS will work with FEMA, NWS, and other relevant agencies to design an integrated program that will modernize techniques for the generation of flood-risk maps, develop a process for routine revision of flood maps, provide near real-time maps of flood inundation areas, and provide forecast maps of flood-inundation areas.

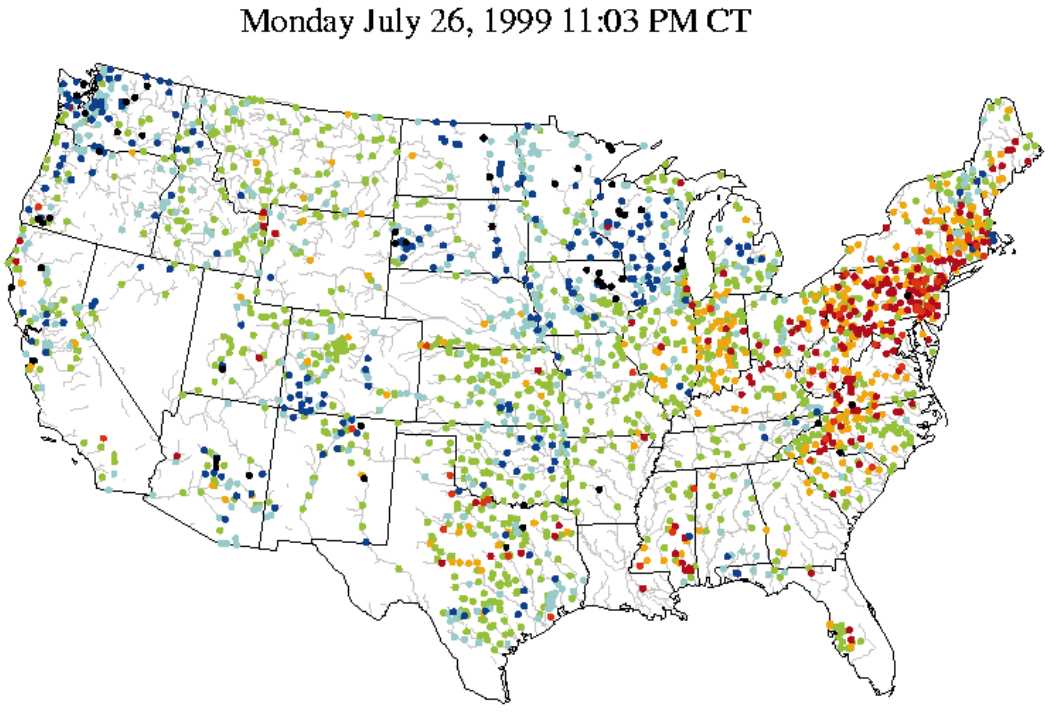

Figure 6. *Real-time flow conditions for gaging stations with 30 years of record or more. Color of dots represent flow conditions: red-orange are low flows, black and blue are high flows.*

Data Processing and Dissemination System

As part of NSIP, the delivery of more real-time data and enhanced hydrologic assessment products will be accomplished by taking advantage of new database design tools and information-delivery technology. Recent advances in computing, telecommunications, and WWW-based information access are changing procedures for processing streamflow data within the USGS. Most important among these changes is the public availability of real-time streamflow data from USGS streamgaging stations. This availability has created significant new interest in water data and presented new challenges for real-time streamflow data processing. A change in data-processing procedures is needed to provide accurate historical and real-time data of known precision within minutes to a broad customer base.

The data routing, archiving and real-time public access components will be co-located at several Data Access Centers. Each Data Access Center will have the same set of data bases, software, and functionality. Duplication of data-serving sites creates a reliable system for providing streamflow information. Several sites could go "offline" due to power failure or communication failure, and streamflow information still could be provided in near real-time over the WWW. The Data Access Centers are intentionally located away from the Data Processing Centers, in order to shield the Data Processing Centers from Internet traffic at the Data Access Centers. At these central processing stations, any poor or missing flow records would be filled in with provisional data generated from flow models that use information from surrounding gages. All flow information served would have uncertainty estimates to define data confidence.

New Technologies

The success of the National Streamflow Information Program will depend on new and original tools and techniques. The most commonly used technique for streamflow estimation (continuous stage measurement, correlated to periodic cross-sectional surveys of velocity using velocity meters) has remained virtually unchanged for a century. For the most part, this is a tribute to its robustness, accuracy, and cost-effectiveness. Concerns for personal safety, accuracy, reliability, and efficiency, however, provide justification for ongoing efforts to identify and develop new and emerging technologies for streamflow measurement. NSIP will pursue research and development on new and emerging technologies for determining river stage, velocity, and discharge without putting people and equipment in contact with the water. Ultimately, the gaging station of the future might operate as shown in figure 7, where stage, cross-section, and water-velocity are all determined by remote sensing from the side of the river, without contact with the stream.

Additional new tools and methods that are required include:

- Development of acoustic doppler current profilers for use in shallow and low-velocity streams and on remotely operated vessels.
- Experimental and theoretical research to develop new, more cost-effective indirect methods of estimating flood flows, to identify processes associated with these flows, and to develop cost-effective means to reconstruct flood peaks that go ungaged or are too dangerous to measure directly. The utility of multi-dimensional flow models and high-resolution digital elevation data will be fully explored in such investigations.
- Improved quality-assurance techniques to screen data for faulty instruments and to quantify the uncertainty of streamflow data.
- Reexamination of the theoretical basis for extrapolating short-term streamgaging station data to 100 and 500-year events to reflect changing climate, land use, and other unidentified controls. This will include an analysis of mixed populations of floods caused by hurricanes, frontal systems, rain on snow, and El Nino and other climatic patterns.

In recent decades, the USGS and others in the scientific community have developed an array of powerful computational tools for modeling of water-

NSIP will identify and develop new and emerging technologies for streamflow measurements.

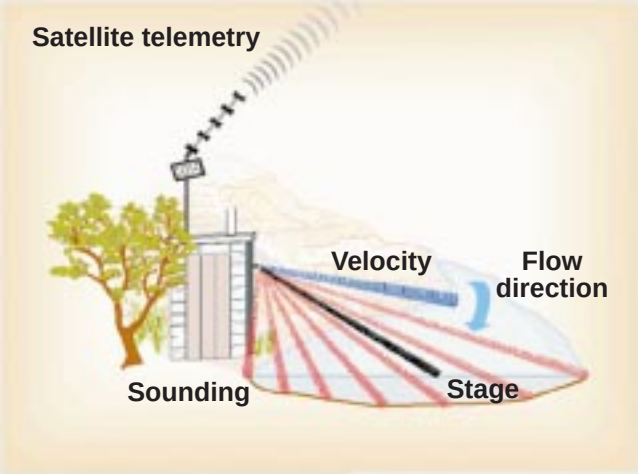

Figure 7. *USGS streamgaging station of the future.*

sheds and stream channels. The USGS will initiate a set of pilot studies to determine the cost-effectiveness of and demand for a national program of model-derived streamflow information products. The USGS also will undertake a program of research into the physical causes of spatial and temporal variations in streamflow characteristics in response to climatic variability and changing land-use practices in many watersheds.

SUMMARY

For over 110 years the United States Geological Survey (USGS), which has no regulatory or developmental responsibilities, has provided unbiased, high-quality streamflow data used by many organizations for many purposes. The USGS operates a collaborative national network of streamgaging stations that meets many Federal, State, and local user needs utilizing multiple sources of funding. This network has evolved over time, but today it is at a crossroads. The need for both real-time data and historical information to support flood and drought mitigation efforts, water-quality and habitat restoration, water-supply planning and other critical needs have stretched the current (1999) network to and in some cases beyond its capabilities. The streamgaging station network needs to be modernized, optimized, and reorganized to be able to answer questions and provide the information needed by a wide community of water-information users.

This plan, which includes enhancements to the streamgaging infrastructure, a new funding mechanism, supplemental measurements of floods and droughts, ongoing assessments of streamflow characteristics and trends, and improved systems for monitoring and disseminating streamflow information, is a step in that direction. This report represents the thoughts of the USGS regarding the future of streamflow information for the Nation. We seek input from all interested parties regarding our vision of NSIP. Comments or questions should be directed to Chief, Office of Surface Water, USGS..

REFERENCES

American Society of Civil Engineers, 1999, Task Committee on GIS Modules, p 63-64.

Cleaves, E.T., 1998, A call for a Federal streamgaging program: Geotimes, October 1998, p. 5.

Committee on U.S. Geological Survey Water Resources Research, 1992, Regional hydrology and the USGS stream gaging network: National Research Council, National Academy Press, Washington, D.C., 24 p.

Committee on Assessing the Costs of Natural Disasters, 1999, The impacts of natural disasters: a framework for loss estimation: National Research Council, National Academy Press, Washington, D.C., 68 p.

Committee on U.S. Geological Survey Water Resources Research, 1999, Hydrologic hazards science at the U.S. Geological Survey: National Research Council, National Academy Press, Washington, D.C., 79 p.

Gebert, W.A. and Krug, W.R., 1996, Streamflow trends in Wisconsin's Driftless area: Water Resources Bulletin, v. 32, p. 733-744.

Stokstad, Erik, 1999, HYDROLOGY: Scarcity of Rain, Stream Gages Threatens Forecasts: Science, Aug. 23, 1999, p. 1199.

U.S. Geological Survey, 1998, A new evaluation of the USGS streamgaging Network: A Report to Congress, 20p.

U.S. Geological Survey, in press, Report of the task force to review the Federal-State Cooperative Water Program, August 1999, Circular No. 1192

Wahl, K.L., Thomas, W.O., Jr., and Hirsch, R.M., 1995, Stream-gaging program of the U.S. Geological Survey: U.S. Geological Survey Circular 1123, 22 p.